

UPPER CRETACEOUS AMMONITES FROM A BOREHOLE NEAR RICHARDS BAY, SOUTH AFRICA

By

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(With 15 figures)

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ABSTRACT

Upper Cretaceous ammonites from a borehole near Richards Bay, South Africa, include *Baculites vanhoepeni*, *Baculites capensis*, *Baculites bailyi*, *Baculites sulcatus*, *Didymoceras* (*D.*) *natalense*, *Madagascarites andimakensis*, *Karapadites* sp. juv., *Hauericeras gardeni*, *Texanites* (*T.*) aff. *T. (T.) soutoni*, *Protexanites* (*Anatexanites*) aff. *P. (A.) nomii*, *Pseudoschloenbachia umbulazi* s.l., *Pseudoschloenbachia* (*Vendegiesiella*) *trituberculata* and *Pseudoschloenbachia* (*V.*) cf. *P. (V.) spinosa*. On the basis of comparisons with faunal successions recognized in Zululand by Kennedy & Klinger (1975) and at Menabe, Madagascar, by Collignon (1969), a Middle or Late Santonian to Early Campanian date is postulated for the fauna in 100 metres of core. The core section is compared with sections of similar age in the False Bay–St Lucia area of Zululand in the north, and Umzamba (Pondoland) to the south, and illustrates the thinning of the Cretaceous section towards the south, and also confirms the diachronism and timing of the Upper Cretaceous transgression in eastern South Africa.

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INTRODUCTION

The presence of fossiliferous subsurface Cretaceous sediments in the Richards Bay area (Natal) (see Fig. 1) appears to have been known as early as 1907, when William Anderson, the one-man Geological Survey of Natal and Zululand, mentioned their occurrence in a borehole 'on the north side of the

Umhlatuzi Lagoon' (1907: 54). On the basis of this information, Cretaceous exposures were indicated at Richards Bay on the 1 : 1 000 000 *Geological Map of the Republic of South Africa and the Kingdoms of Lesotho and Swaziland* (compiled by Coertze and Schifano in collaboration with Van Eeden 1970). Excavations for a bridge near the Enseleni River, west of Richards Bay in 1970 (Kennedy & Klinger 1975: 282, Locality 6) yielded Santonian and Campanian ammonites from what the authors believed to be an interval of only 15 metres. Unfortunately, however, the exact stratigraphic sequence of the fauna was not established, as the material came from rubble heaps.

In view of the construction of fuel berths and other facilities associated with the development of a new harbour at Richards Bay, an extensive drilling programme was initiated in the area in order to test the petrophysical properties of the subsurface materials (see Maud & Orr 1975: 101 for more data).

Excavations for a coal berth had, in the meantime, revealed the presence of a substantial thickness of Palaeocene sediments (Orr & Chapman 1974), overlying the Cretaceous unconformably, and microfaunal assemblages from above and below the Cretaceous/Tertiary contact were described by Stapleton (1975).

In fresh specimens the Palaeocene and Cretaceous sediments have the same colour and texture, and it seems very likely that Anderson's 1907 report of Cretaceous sediments may in fact have been based in part on Palaeocene deposits as well.

The authors were able to examine the core of borehole BH9, 14 km to the west of Richards Bay township. The locality of the borehole is indicated as Borehole W in the map of Maud & Orr (1975: 102, fig. 1). The core has a diameter of 50 mm, is 159 metres long, and penetrated to granite-gneiss Basement rocks. The lithologies are of predominantly dark green-grey silts with occasional concretionary layers of a slightly lighter colour. The top 60 metres of core were very weathered, and no macrofossils could be extracted. The lower 100 metres of the core were very fossiliferous, and in places the preservation was superb. Many of the fossils have retained their original aragonitic shell mineralogy, and fine details of ornament and structure, which are normally destroyed, are preserved (see also Maud & Orr 1975: 103).

A very detailed faunal succession has been recognized in the fossiliferous 100 metres of section, and the authors have been able to correlate the Richards Bay core with the Upper Cretaceous sequences of the False Bay-St Lucia area of Zululand to the north, and the coastal outcrops at Umzamba (Pondoland) to the south (Fig. 1). From these data the authors have been able to determine further the extent of the diachronous Upper Cretaceous transgression in eastern South Africa (Kennedy & Klinger 1971) and further document the southerly attenuation of the whole of the Cretaceous System.

In drawing stratigraphic boundaries in the Richards Bay borehole, the biostratigraphic divisions recognized in Natal and Zululand by Kennedy & Klinger (1975) and those recognized at Menabe, Madagascar, by Collignon (1969) have

been applied, and tested in an unequivocal succession far better in terms of continuity than any surface outcrops described to date.

Detailed descriptions of the regional distribution of the Cretaceous System in Natal and Zululand and along the Pondoland coast are given by Kennedy & Klinger (1971), Kennedy *et al.* (1973), Kennedy & Klinger (1975) and Klinger & Kennedy (in press),* and need not be repeated here, whilst full details of the subsurface extent of the Cretaceous sediments in the Richards Bay area are provided by Maud & Orr (1975).

The systematics of some of the species to be described are in need of full revision; this is especially true of the baculitids, texanitids and pseudoschloenbachiids. A revision of these groups based on the borehole material alone is not advisable, and taxa recognized in the systematic descriptions below conform with current specific and generic concepts, pending the authors' further work on material from surface outcrops.

Unless otherwise mentioned, all material described below is housed in the collections of the Geological Survey of South Africa, Pretoria.

SYSTEMATIC DESCRIPTIONS

Phylum MOLLUSCA

Class CEPHALOPODA Zittel, 1884

Order AMMONOIDEA Zittel, 1884

Suborder ANCYLOCERATINA Wiedmann, 1966

Superfamily TURRILITACEAE Meek, 1876

Family **Baculitidae** Meek, 1876

Genus *Baculites* Lamarck, 1799

Baculites capensis Woods, 1906

Figs 2A–F, 3G

Baculites capensis Woods, 1906: 342, pl. 44 (figs 6–7). Spath 1921: 257, pl. 24 (figs 6–7); 1922: 146. Venzo, 1936: 116. Matsumoto, 1959: 121, pl. 33 (figs 1–3), pl. 45 (figs 1–4), text-figs 33–34. Matsumoto & Obata, 1963: 47, pl. 14 (fig. 2), pl. 15 (figs 3–5), pl. 19 (fig. 2), text-figs 95–96, 147–151. Collignon, 1966: 6, pl. 457 (fig. 1862).

Baculites aff. *B. capensis* Woods; Spath, 1921: 258. Collignon, 1931: 22, pl. 3 (fig. 6). Anderson, 1958: 192, pl. 48 (figs 8, 8a).

Baculites capensis Woods var. *umsinensis* Venzo, 1936: 116, pl. 10 (6) (figs 13a–b).

Baculites capensis Woods var. *tenuetuberculata* Collignon 1966: 6, 22, pl. 457 (figs 1863–1864), pl. 463 (figs 1894–1895).

? *Baculites* cf. *B. aspero-anceps* Lasswitz; Spath, 1921: 259, pl. 24 (figs 4, 4a).

Baculites buttensis Anderson, 1958: 191, pl. 49 (fig. 6).

Baculites cf. *B. brevicostata* Schlüter; Spath, 1921: 260, pl. 24 (figs 5, 5a).

* Due to delays beyond control of the authors this may possibly appear in print at a later date—after the present publication.

Lectotype

The original of Woods (1906, pl. 44 (fig. 6a-b)) by subsequent designation Matsumoto & Obata (1963: 48) and here refigured as Fig. 2B-D.

Material

BH9/148a, BH9/148,50, BH9/158, BH9/137,4. (The figures following BH9 indicate the depth in metres of the core.)

Description

Numerous baculitid fragments occur in the basal part of the core, just above the contact with the Basement schists, in some places forming a *Baculites* mélange. Better preserved material is available from a depth of 148 metres. At a diameter of 4 mm the shell is still smooth and devoid of tuberculation, but shows a high expansion rate. BH9/148a (Fig. 2A) is an adult and resembles the type specimen most closely, even though the tubercles are more conical, rather than longitudinally elongated. It also lacks the longitudinal furrow ventral to the tubercles which is so obvious in the type specimen, whilst the spacing of tubercles is irregular. BH9/137,4 (Fig. 3G) has a similar whorl section, but only three small, crescentic dorso-lateral tubercles and lateral striae.

The suture line is not visible on any of the specimens.

Discussion

None of the present specimens completely fits the illustration and description of the lectotype, here refigured as Figure 2B-D, but in view of the extreme variation encountered in the species are most suitably placed here. The Richards Bay material corresponds to Collignon's *B. capensis* variety *tenuetuberculata* which occurs in the Lower and Middle Santonian of Madagascar.

The specimens described by Spath (1921: 259, 260) as *Baculites* cf. *B. aspero-anceps* and *Baculites* cf. *B. brevicostata* are no more than intra-specific variants of *B. capensis*. *Baculites* cf. *B. aspero-anceps* is comparable with BH9/148a (Fig. 2A) and *B. cf. B. brevicostata* with BH9/137,4 (Fig. 3G).

The specimens described by Kennedy & Klinger (*in* Kennedy *et al.* 1973) under the name of *Baculites* sp. group of *Baculites capensis* are most probably Lower Campanian descendants of *B. capensis*; they are referred to *B. vanhoepeni* Venzo (= *B. tanakae* Matsumoto & Obata) below. This latter species differs from *B. capensis* in having auricular tuberculation rather than showing longitudinal elongation of the tubercles.

The affinities of *B. capensis* are discussed further by Matsumoto (1959: 121 *et seq.*) and Matsumoto & Obata (1963: 47 *et seq.*).

The relative abundance of baculitids near the base of the Richards Bay core, close to the transgressive unconformable contact, may be the result of some ecological controls on their distribution, for Maud & Orr (1975: 103) consider this part of the sequence to be a relatively shallow water facies when compared to the rest of the sequence.

Occurrence

At the type section of the Umzamba Formation, Umzamba Cliff (Kennedy & Klinger's 1975 Locality 1; see Figure 12), *B. capensis* occurs in bed Pii1, of late Middle or early Late Santonian age. In Madagascar the species and its varieties occur in the Early and Late Santonian. In Zululand occurrences are mainly restricted to the Late Coniacian and Santonian. The Japanese occurrences are of Santonian age. In California the species occurs in the Early Santonian.

Baculites vanhoepeni Venzo

Figs 2G–K; 3A, H–I; 4A–C; 5C

Baculites vagina Forbes var. *van hoepeni* Venzo 1936: 116, pl. 10 (6) (figs 11–12).

? *Baculites tanakae* Matsumoto & Obata, 1963: 51, pl. 13 (fig. 4), pl. 16 (figs 1–5), pl. 17 (figs 1–5), pl. 18 (figs 1, 3, 4), pl. 19 (figs 1–4), text-figs 97–113, 115.

Baculites sp. group of *Baculites capensis* Kennedy & Klinger, 1973: 100, pl. 4 (figs 1–5), pl 5 (figs 1a–d), pl. 6 (figs 4–5).

Baculites sulcatus (non Baily); Kennedy & Klinger, 1975: 280.

Lectotype

The specimen figured by Venzo (1936: 116, pl. 10 (6), fig. 11a–b) is herein designated lectotype of the species.

Material

BH9/81,85, BH9/83, BH9/85,93, BH9/87, BH9/88,71, BH9/88,8, BH9/88,9, BH9/89.

Description

The expansion rate is high during the early growth stages, declining subsequently, although specimens may attain a large size. The intertubercular cross-section is sub-rounded triangular in the early stages with a broadly rounded dorsum and little inflated flanks, which converge to a narrow venter. With increasing diameter the venter broadens, until, in the adult stage, it equals the dorsum in width.

Adult ornament consists of large, widely spaced auricular tubercles which may cover half to two-thirds of the dorsal part of the flank. Apart from the tubercles, striae are present, and these sweep forward in an apertural direction over the flanks, and show a distinct forward curvature across the dorsum and venter.

The size and stage of appearance of tubercles is variable. The tubercles may be prominent and auricular (e.g. Fig. 2H–K) or merely slightly elongated nodes on the flanks (e.g. Fig. 2G). Specimens such as BH9/88,71 (Fig. 5C) are still completely smooth at a whorl height of 11 mm, whereas other specimens, as for example BH9/88,3 (Fig. 3H), already show auricular swellings at a whorl height of 10 mm. Specimen BH9/87 (Fig. 3I) shows the transition from the smooth to the tuberculate stage.

The suture line is only partially exposed in one specimen.

Discussion

Identical material was described from the subsurface deposits of Durban by Kennedy & Klinger (*in* Kennedy *et al.* 1973: 100, pl. 4 (figs 1–5), pl. 5 (fig. 1a–d), pl. 6 (figs 4–5)) as *Baculites* sp. group of *Baculites capensis*. Because of the extreme variation and lack of stratigraphic control no attempt at definite identification was made, the material being referred to the group of the first-described South African baculitid with strong lateral ornament. Examination of the Richards Bay material, however, has shown that these specimens and the Durban material are identical to those from Locality 110 in Zululand (Kennedy & Klinger 1975) referred to as *Baculites sulcatus* (= *Baculites vagina* Forbes var. *van Hoepeni* Venzo) (Kennedy & Klinger 1975: 280). The latter is a misidentification; *Baculites vagina* var. *van Hoepeni* is probably a senior synonym of *Baculites tanakae* Matsumoto & Obata, and is quite unrelated to the Maastrichtian *Eubaculites vagina* (Forbes). An adult form of *B. vanhoepeni* SAS A2035 from Zululand is figured here (Fig. 4A–C).

The South African material differs from the Japanese specimens of *B. tanakae* mainly in having a more or less rounded venter in the adult stage and stronger lateral ornament. The absence of a fastigate venter and the stronger ornament are thought to be within the limits of intraspecific variation. Transitions occur towards *B. capensis*, from which the species is probably descended (see Matsumoto & Obata 1963: 54); examples include BH9/100 (Fig. 2G), which has essentially rounded tubercles. Generally, however, *B. capensis* has longitudinally elongated tubercles, whereas *B. vanhoepeni* has auricular ornament.

Through weakening of lateral ornament in the adult stage, closer spacing thereof, and acquisition of a more fastigate venter, there arise transitions towards the slightly younger *Baculites sulcatus*, to be described below.

A closely related, but apparently somewhat younger species is *Baculites boulei* Collignon (1931: 35, pl. 5 (figs 2–2a), pl. 9 (fig. 14)). (See also Matsumoto 1959: 118, pl. 32 (fig. 7a–c), pl. 33 (figs 4a–c, 5a–b, 6a–d, 7a–b), text-figs 27a–b, 28–32; Matsumoto & Obata 1963: 43, pl. 13 (figs 3, 5), pl. 15 (fig. 6), text-figs 93, 152–155.) Matsumoto & Obata's illustrations of *B. boulei* show that the whorl section in the Japanese material is similar to that of the Richards Bay specimens in having a narrower venter than dorsum in the early stages. According to Matsumoto, *B. boulei* occurs in the Upper Urakawan, which is equivalent to the Upper Santonian.

A number of *Baculites* species occur in the upper part of the Lower Campanian of Madagascar which probably all fall in the range of variation of the present species, as suggested earlier (Kennedy & Klinger *in* Kennedy *et al.* 1973: 100). These include *B. menabensis* Collignon (1969: 15, pl. 518 (figs 2036–2037)), *B. antsiraensis* Collignon (1969: 18, pl. 519 (figs 2040–2041)), *B. subtilis* Collignon (1969: 20, pl. 519 (figs 2042–2044)), *B. falcatus* Collignon (1969: 20, pl. 520 (figs 2045–2047)), *B. ventroplanus* Collignon (1969: 20, pl. 520 (figs 2048–2050), pl. 531 (figs 2056–2058)) and *B. sparsinodosus* Collignon (1969: 23, pl. 521 (figs 2052–2054)). To this list may be added *Baculites bassei* Besairie

(1930: 222, pl. 22 (figs 8, 8a)), although a thorough study of these 'species' is necessary to confirm this.

Occurrence

Baculites vanhoepeni (= *tanakae*) occurs in the second division of the Campanian in Zululand at localities 110 and 114 and in the Early Campanian of Japan. Allied Madagascan 'species' all occur in the upper part of the Lower Campanian Zone of *Menabites boulei* and *Anapachydiscus arrialoorensis*.

Baculites bailyi Woods, 1906

Fig. 5D

Baculites sulcatus Baily, 1855: 457, pl. 11 (fig. 5a–b) only.

Baculites bailyi Woods, 1906: 341, pl. 44 (fig. 5). Van Hoepen, 1921: 18, pl. 3 (figs 9–10). Spath, 1921: 261. Matsumoto & Obata, 1963: 35, pl. 20 (figs 1–2), pl. 21 (fig. 5), text-figs 88–89, 116–120, 140–142. Collignon, 1969: 21, pl. 520 (fig. 2050).

Holotype

BMNH 11372, the specimen figured by Baily (1855, pl. 11 (fig. 5a–b)) only.

Material

BH9/104.

Description and discussion

A single, septate fragment is referred to the species. The whorl section is rounded, slightly higher than wide. Ornament consists of fine striae only, and, what appears to be a shallow constriction, which parallels the striae.

At one stage the authors considered the possibility that *B. bailyi* might represent the juvenile stage of *B. vanhoepeni*. Comparison with other specimens of this rare species shows, however, that the rounded whorl section clearly separates it from *B. vanhoepeni* in the early stages. (For a full discussion of the species see Matsumoto & Obata, 1963: 35 et seq.)

Besairie's (1930, pl. 21 (fig. 6)) specimen is definitely not *B. bailyi*; it has quite conspicuous lateral nodes, and should most probably be referred to *B. capensis* or one of the allied nodose species.

Occurrence

The species occurs in the Early Campanian of Pondoland, the Santonian of Japan and in the Early Campanian Zone of *Menabites boulei* and *Anapachydiscus arrialoorensis* in Madagascar.

Baculites sulcatus Baily, 1855

Fig. 3B–E, J–L

Baculites sulcatus Baily, 1855: 457, pl. 11 (fig. 5c only). Woods, 1906: 341, pl. 44 (fig. 4).

Van Hoepen, 1921: 18, pl. 3 (figs 7–8). Spath, 1922: 146. Collignon, 1931: 36, pl. 5 (figs 3, 3a, 4, 4a, 5, 5a, 13, 13a), pl. 9 (fig. 15).

Baculites cf. *B. sulcatus* Baily, Spath, 1921: 260.

? *Baculites* cf. *B. tanakae* Matsumoto & Obata, Collignon, 1969: 23, pl. 521 (2055).

Lectotype

The specimen figured by Baily (1855, pl. 11 (fig. 5c) only), refigured by Woods (1906, pl. 44 (fig. 4)), designated by Matsumoto & Obata (1963: 46).

Material

BH9/64a, b, c from Richards Bay Borehole BH9, SAM-PCP 5684, SAM-PCP 5685 (South African Museum) and D1663 (National Museum, Bloemfontein), from Umzamba.

Description

The whorl section is ovate, higher than wide, with a broadly rounded dorsum and a sharply acute venter. The whorl section remains essentially similar throughout ontogeny. At a dorsoventral diameter of as little as 7 mm the characteristic ornament is developed; strong, crescentic ribs are present on the dorsal shoulder and are connected across the dorsum by a characteristic broad swelling. Over the ventral half the ribs curve acutely forward, narrowing as they do so, and eventually pass over the venter with a marked chevron. Intercalated riblets may arise at midflank; they also pass over the venter, or they may arise in pairs from the ventral half of the crescentic rib. The chevron ornament over the venter and the thick ribs connecting the lateral ribs over the dorsum are characteristic of the juvenile stage of the species.

With increase in diameter (which is rapid) ornament becomes very much attenuated, and the venter and dorsum are no longer ornamented by strong sulcae. Even though ornament is weakened, the flanks are still characterized by the crescentic ribs from which may arise a series of striae, whilst intercalatory striae are also developed and pass forwards over the flanks. The lateral ornament is closely spaced.

Discussion

This is a relatively scarce and poorly understood species, being so far known only from juvenile specimens. Baily (1855) included what Woods (1906: 341) later called *B. bailyi* in his *Baculites sulcatus*, and only figured the characteristic sulcate ornament of the venter of the juvenile type specimen. Woods (1906: 341, pl. 44 (fig. 4)) figured the type specimen in lateral view, showing it to be totally different from the lateral views of *B. bailyi* as illustrated in Baily (1855, pl. 11 (fig. 5a)). Van Hoepen (1921: 18, pl. 3 (figs 7–8)) figured additional typical examples featuring the robust juvenile ornament. To the authors' knowledge the largest collection of specimens of *B. sulcatus* is in the Van Hoepen Collection in the Transvaal Museum, Pretoria, but again all specimens are juvenile. The strong lateral ornament of the juvenile specimens led the authors to believe that *Baculites vanhoepeni* Venzo was a junior synonym of *B. sulcatus* (Kennedy & Klingler 1975: 280). Recent detailed collecting at the type section of the Umzamba Formation at Umzamba Cliff by one of the authors (H. C. K.) (Klinger & Kennedy, in press), plus the recovery of the Richards Bay material, have shown that *Baculites vagina* var. *van Hoepeni* Venzo 1936 is a related, but slightly older

species. *Baculites sulcatus* differs from *B. vanhoepeni* (as here interpreted) in having closer-spaced and weaker lateral ornament in the adult stage, and a more acute venter.

Baculites sp. nov. aff. *B. sulcatus* Matsumoto & Obata (1963: 46, pl. 12 (fig. 6), text-figs 94, 130) has a densely sulcate venter when young, but lacks the strong lateral ornament of juveniles of *B. sulcatus*.

Baculites capensis Woods (1906: 342, pl. 44 (figs 6–7)) is an older species (Early to Late Santonian), has a smooth early stage and generally has longitudinally elongated tubercles when adult.

Baculites columna Morton (see Matsumoto 1959: 126, pl. 34 (fig. 1) especially) also has comparable, but much stronger ornament.

Specimens of *Baculites ovatus* (see Cobban 1974: 3, pl. 1 (figs 1–32), pl. 2 (figs 1–14), pl. 3 (figs 1–6, 9–11), text-fig. 4) may have similar lateral ornament, but typically the species has an ovoid whorl section.

Collignon's (1931: 23, pl. 5 (figs 3–5)) specimens, referred to *B. sulcatus*, all lack lateral ornament, and only show a densely sulcate venter, so that it is questionable whether or not they should be referred to Baily's species.

To summarize, therefore, *Baculites sulcatus* has strong lateral, ventral and dorsal ornament in the juvenile stage, but loses this, eventually possessing only closely spaced crescentic lateral ribs and a subtrigonal whorl section with an acute venter when adult.

Occurrence

Baculites sulcatus occurs in the Early Campanian part of the Umzamba Formation. At the type section (Fig. 12) it was found in beds Pi15 and Pi14, approximately the equivalent of Kennedy & Klinger's (1975) second division of the Campanian in the False Bay area of Zululand.

Family *Nostoceratidae* Hyatt, 1894

Subfamily *Nostoceratinae* Hyatt, 1894

Genus *Didymoceras* Hyatt, 1894

(= *Nostoceras* Hyatt, 1894)

Didymoceras (*Didymoceras*) *natalense* (Spath, 1921)

Fig. 5E

Nostoceras ? *natalense* Spath, 1921: 243, pl. 22 (figs 2a, b).

Holotype

The specimen figured by Spath (1921, pl. 22 (figs. 2a–b)), housed in the South African Museum, Cape Town.

Material

BH9/117.

Description

A single specimen consisting of one and a quarter slightly crushed whorls of the phragmocone is referred to Spath's species.

Coiling is moderately tight with only a small impressed dorsal zone. The apical angle is estimated at approximately 110 degrees. The dorsal part of the whorls is ornamented by fine, prorsiradiate curving ribs which join in pairs on the dorsal third of the flanks to pointed tubercles. Another row of tubercles is visible at the upper whorl suture. Due to the crushed state of the specimen it is not possible to determine whether ribs join the tubercles in pairs or not. The central part of the whorls bears similar ribs to those on the dorsum.

Discussion

The holotype of the species, SAM-K2744, is a badly worn adult, but on the earliest whorl preserved, traces of looped ribbing, similar to that of the present specimen are visible.

The systematics of the Nostoceratinae are in a state of flux at present, but *D. (D.) natalense* has affinities with '*Turrilites (Bostrychoceras) schloenbachi* (Favre) (in Basse 1931: 19, pl. 2 (figs 11–15)) (see also Collignon 1969, pl. 644 (figs 2385–2386)) and in *Nostoceras? obtusum* Howarth (1965: 348, pl. 10 (fig. 2), text-fig. 2) (see also Collignon 1969, pl. 643 (fig. 2375)).

Occurrence

Spath's specimen was probably collected at Kennedy & Klinger's (1975) locality 10, Umkwelane Hill, near Mtubatuba; rocks of Coniacian to Campanian age are exposed in the area. Another specimen in the Geological Survey Collections was found high in the Campanian of the St Lucia area. The Madagascan species with which *D. (D.) natalense* are compared all occur in the Early Maastrichtian.

Genus *Madagascarites* Collignon, 1966

Madagascarites andimakensis Collignon, 1966

Fig. 5F

Madagascarites andimakensis Collignon, 1966: 26, pl. 465 (figs 1897–1898).
? *Hyphantoceras ingens* Collignon, 1966: 24, pl. 464 (fig. 1896).

Material

BH9/137.

Description

One specimen, comprising part of a body chamber whorl with a circular cross-section, ornamented by eight to nine narrow oblique ribs, separated by interspaces two to three times wider than themselves, is referred to the species. Two pairs of quadrituberculate, looped ribs occur separated by three intermediaries. The tubercles are conical, and situated at the juncture of two ribs, in a distinctive button and loop arrangement.

Discussion

Madagascarites is a very rare genus, thus far known only from the type species and *Madagascarites ryu* Matsumoto & Muramoto (1967: 362, pl. 19 (fig. 3), pl. 22 (fig. 1), pl. 23 (figs 1–4)) from Japan. '*Hyphantoceras*' *ingens* Collignon (1966: 24, pl. 464 (fig. 1896)) has ornament similar to that of the type species, and is probably conspecific, being merely a more densely ribbed variant.

The Richards Bay fragment does not allow for comparisons to be made with the Madagascan material as far as coiling is concerned, but in terms of ornamentation, the similarity is so close as to merit reference to the species.

The specimen differs from the types of *M. ryu* Matsumoto & Muramoto in that that species has much finer, denser ribbing.

Suborder AMMONITINA Hyatt, 1889

Superfamily DESMOCERATAEAE Zittel, 1895

Family *Kosmaticeratidae* Spath, 1922

Genus *Kosmaticeras* De Grossouvre, 1901

Subgenus *Karapadites* Collignon, 1954

Kosmaticeras (*Karapadites*) sp. juv. indet.

Fig. 6D

Material

A silicone rubber squeeze, BH9/102,6 taken from a small external mould.

Description and discussion

The presence of umbilical tubercles and absence of ribbing at midflank on this kosmaticeratid fragment, together with the fine ribbing towards the venter, suggest reference to *Karapadites*. A few constrictions appear to be present on the inner whorls. The specimen is specifically indeterminate.

Occurrence

A number of species of *Karapadites* have been described from Madagascar by Collignon (1954, 1966, 1969). The majority occur in the upper part of the Early Campanian zone of *Karapadites karapadensis*, but other species occur as early as Middle Santonian.

Family **Desmoceratidae** Zittel, 1895
 Subfamily **Hauericeratinae** Matsumoto, 1938
 Genus *Hauericeras* De Grossouvre, 1894

Hauericeras gardeni (Baily, 1855)
 Figs 7A–C, 8A

Ammonites gardeni Baily, 1855: 456, pl. 11 (figs 3a–c).

Hauericeras (Gardeniceras) gardeni (Baily); Matsumoto & Obata, 1955: 140 text-figs 8–10.
 Collignon, 1961: 76, pls 28–30, text-figs 13–14 (with synonymy); 1969: 66, pl. 819 (fig. 2114).

Hauericeras cf. *H. gardeni* (Baily); Kennedy & Klinger, 1973: 101, pl. 6 (figs 2a–c).

Material

BH9/120,22, BH9/124, BH9/127,80.

Description

BH9/120,22 (Fig. 7B) is the most complete specimen, consisting of parts of two successive whorls, with the shell preserved on one side only. At the end of the phragmocone a constriction is visible on the internal mould. The constriction is visible only on the flanks and is completely absent on the dorsum, and also appears to have been absent over the venter. On the side where the shell is preserved, the constriction is barely visible.

BH9/124 consists of two halves of a crushed specimen, and is referred to the species on the basis of the presence of the keel, smooth flanks and the characteristic suture line.

In BH9/127,80, part of the original aragonitic shell has been preserved, permitting a view of the interior. The mode of attachment of the septae to the inner shell layer is beautifully displayed (Fig. 7A). The siphuncle is not preserved, but on either side of, and along the siphonal line, rows of shallow pits are prominent on the inner shell-layer, corresponding to what must be the bases of conellae on the inner part of the floor of the hollow keel (Fig. 8A).

Discussion

Hauericeras angustum (Yabe) (1904: 33, pl. 5 (figs 5–6)) and *Hauericeras madagascariense* Collignon (1961: 81, text-figs 15–17, pl. 31 (figs 1, 1a–b), pl. 32 (figs 1, 1a)) are closely allied species. Both, however, differ in having a lower and broader whorl section. For details of differences between *H. gardeni* and *H. angustum* see Matsumoto & Obata (1955: 140).

Occurrence

In Madagascar *H. gardeni* ranges from the Late Santonian Zone of *Pseudoschloenbachia umbulazi* to the Middle Campanian Zone of *Pachydiscus lamberti*. In Zululand the succession is not quite as clear, but *H. gardeni* appears to range to the first division of the Campanian. At the type section of the Umzamba Formation (Fig. 12) the species was found in beds Pi3 to Pi7, being most abundant in bed Pi7, at the Santonian–Campanian boundary. *H. gardeni* appears to be restricted to southern Africa and Madagascar.

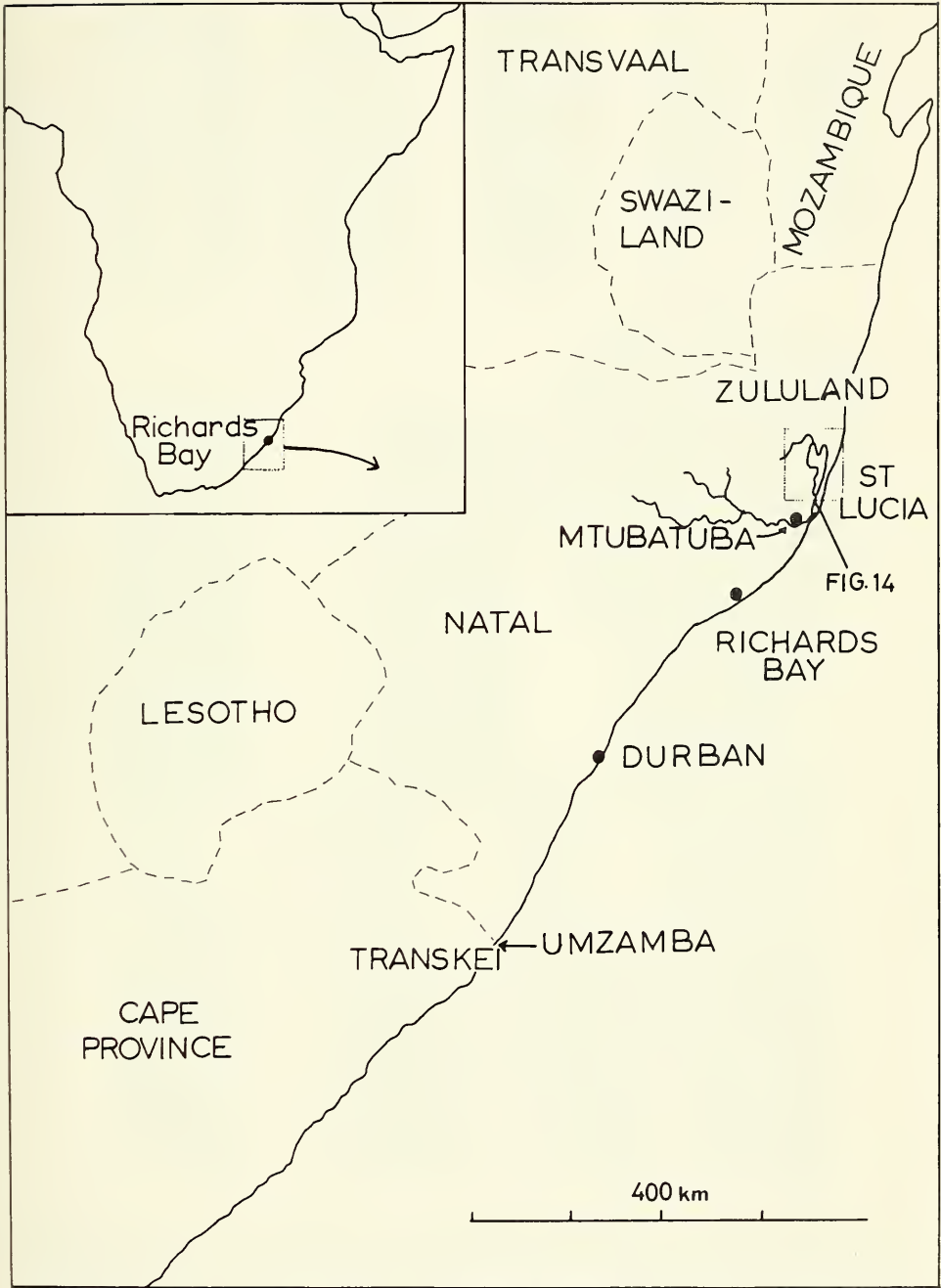


Fig. 1. Locality map of the area.

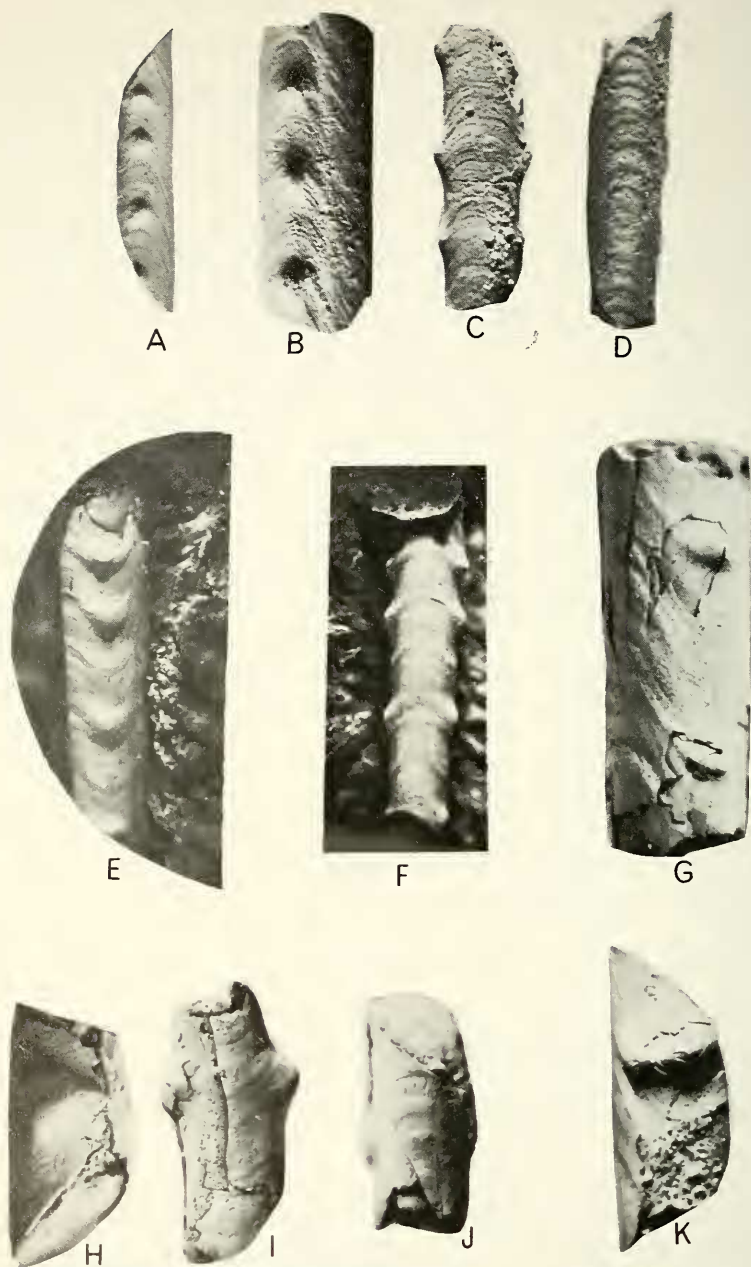


Fig. 2. A. *Baculites capensis* Woods, 1906. BH9/148,50 ($\times 1$). B, C, D. *Baculites capensis* Woods, 1906. Lectotype figured by Woods, 1906, pl. 44 (fig. 6a-b) ($\times 1$). E, F. *Baculites capensis* Woods, 1906. BH9/148 ($\times 1$). Specimen with lateral ornament approaching that of *B. vanhoepeni* Venzo, 1936. G. *Baculites vanhoepeni* Venzo, 1936. BH9/100 ($\times 1$). Specimen with lateral ornament approaching that of *B. capensis* Woods, 1906. H, I, J. *Baculites vanhoepeni* Venzo, 1936. BH9/88,80 ($\times 1$). Specimen with typical auricular lateral ornament. Note faint crinkly structure on flank and on venter. K. *Baculites vanhoepeni* Venzo, 1936. BH9/89 ($\times 1$).

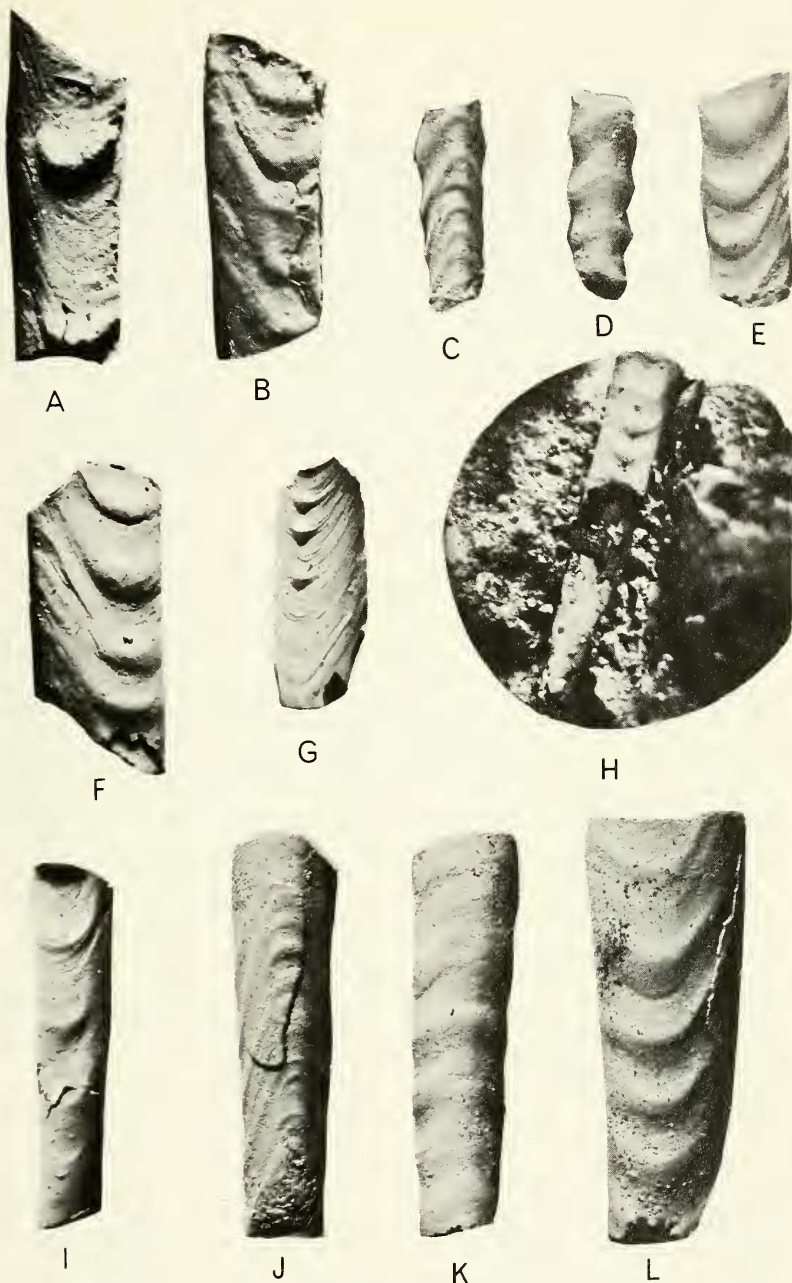


Fig. 3. A. *Baculites vanhoepeni* Venzo, 1936. BH9/81,59 ($\times 1$). B. *Baculites sulcatus* Baily, 1855. BH9/64a ($\times 0,8$). C, D, E. *Baculites sulcatus* Baily, 1855. SAM-PCP5684 ($\times 1,2$). Juvenile specimen with robust ornament. F. *Baculites sulcatus* Baily, 1855. BH9/64b ($\times 0,8$). Adult specimen with weakened ornament. G. *Baculites capensis* Woods, 1906. BH9/137,4 ($\times 1$). Specimen with weak, crescentic tubercles. H. *Baculites vanhoepeni* Venzo, 1936. BH9/88,39 ($\times 1$). I. *Baculites vanhoepeni* Venzo, 1936. BH9/87 ($\times 1$). Specimen featuring transition from smooth to tuberculate stage. J, K, L. *Baculites sulcatus* Baily, 1855. SAM-PCP5685 ($\times 1,2$). Adult specimen showing weakening of ornament.

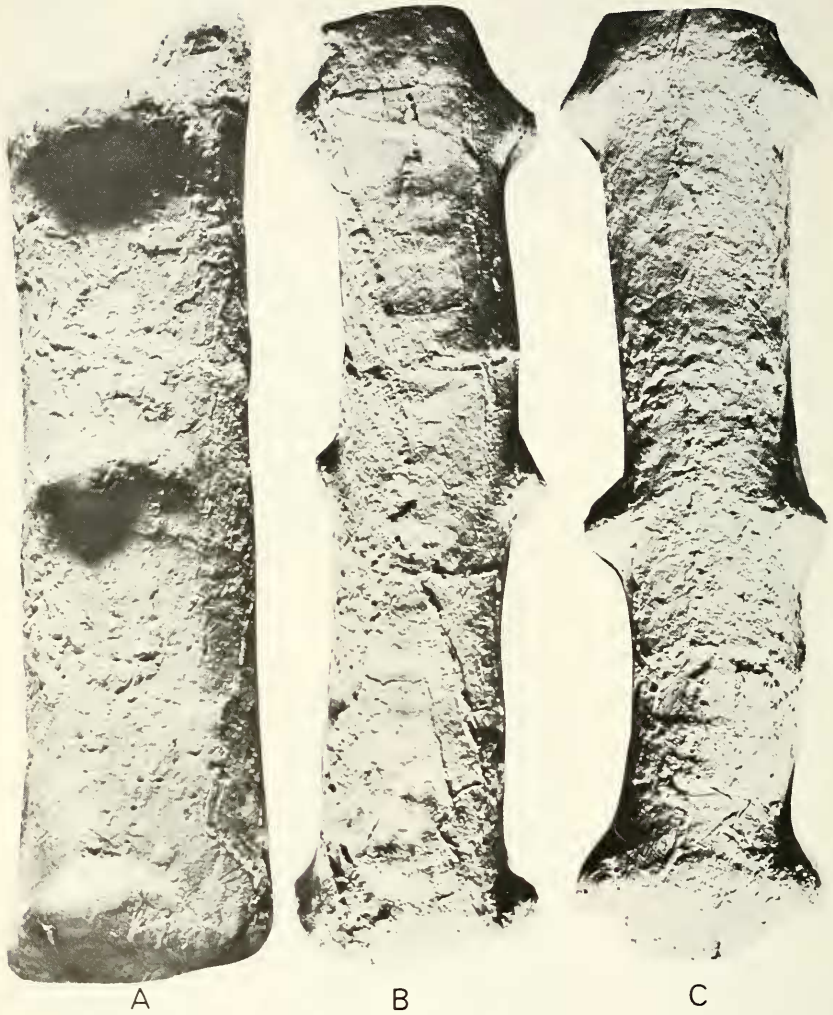


Fig. 4. A, B, C. *Baculites vanhoepeni* Venzo, 1936. SAS A2035 ($\times 1$). Adult specimen from locality 109, Zululand, with strong, auricular lateral ornament.

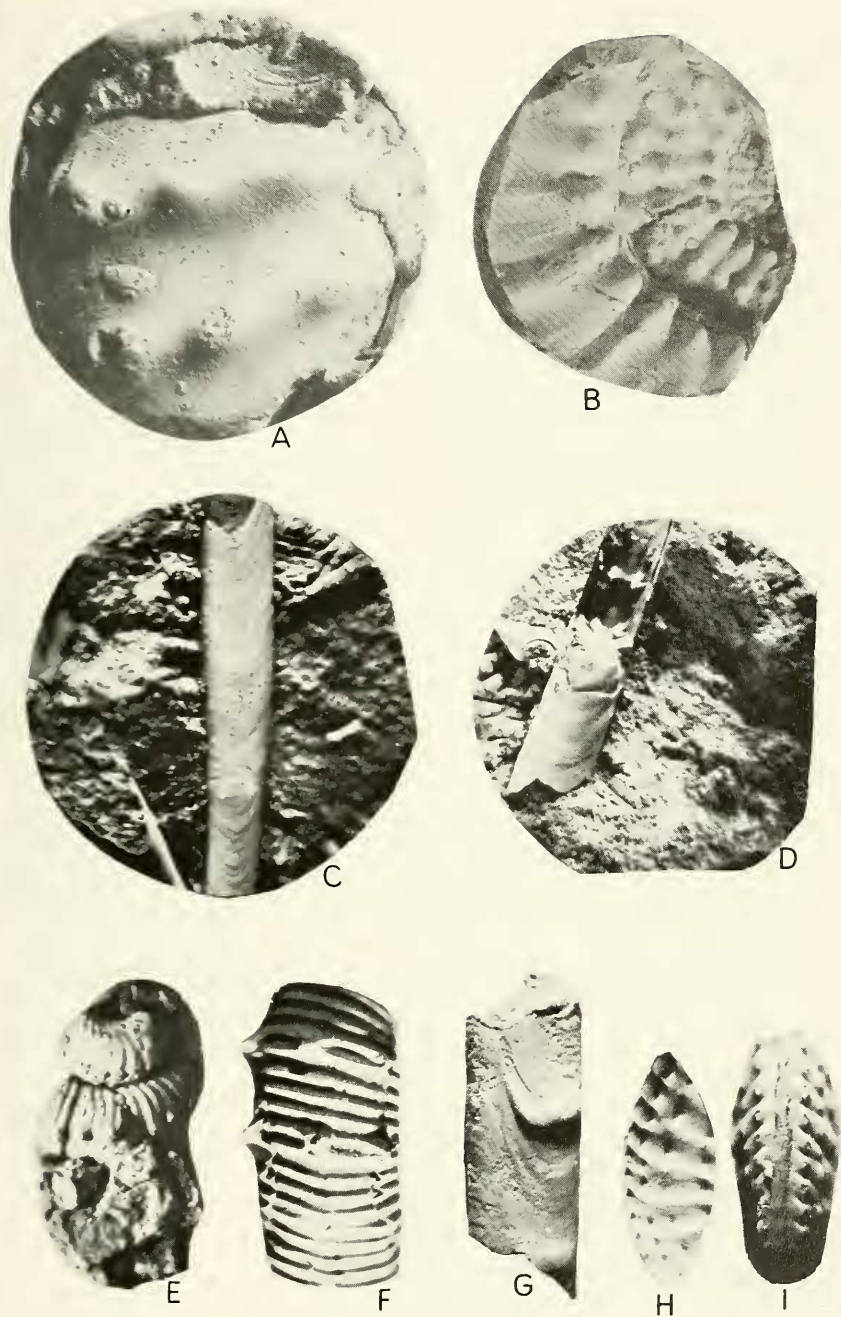


Fig. 5. A. *Texanites* (*T.*) sp. aff. *T. (T.) soutoni* (Baily, 1855). BH9/128 ($\times 1$). B. *Texanites* (*T.*) sp. aff. *T. (T.) soutoni* (Baily, 1855). BH9/116 ($\times 1$). Silicone rubber squeeze of remains of specimen figured in Figure 10B-C. C. *Baculites vanhoepeni* Venzo, 1936. BH9/86,76 ($\times 1$). Specimen retaining smooth, juvenile stage to large diameter. D. *Baculites bailyi* Woods, 1906. BH9/104 ($\times 1$). E. *Didymoceras* (*D.*) *natalense* (Spath, 1921). BH9/117 ($\times 1$). F. *Madagascarietes andimakensis* Collignon, 1966. BH9/137 ($\times 1$). G. *Baculites vanhoepeni* Venzo, 1936. BH9/85 ($\times 1$). H, I. *Bevahites* sp. indet. BH9/101,7 ($\times 1$).

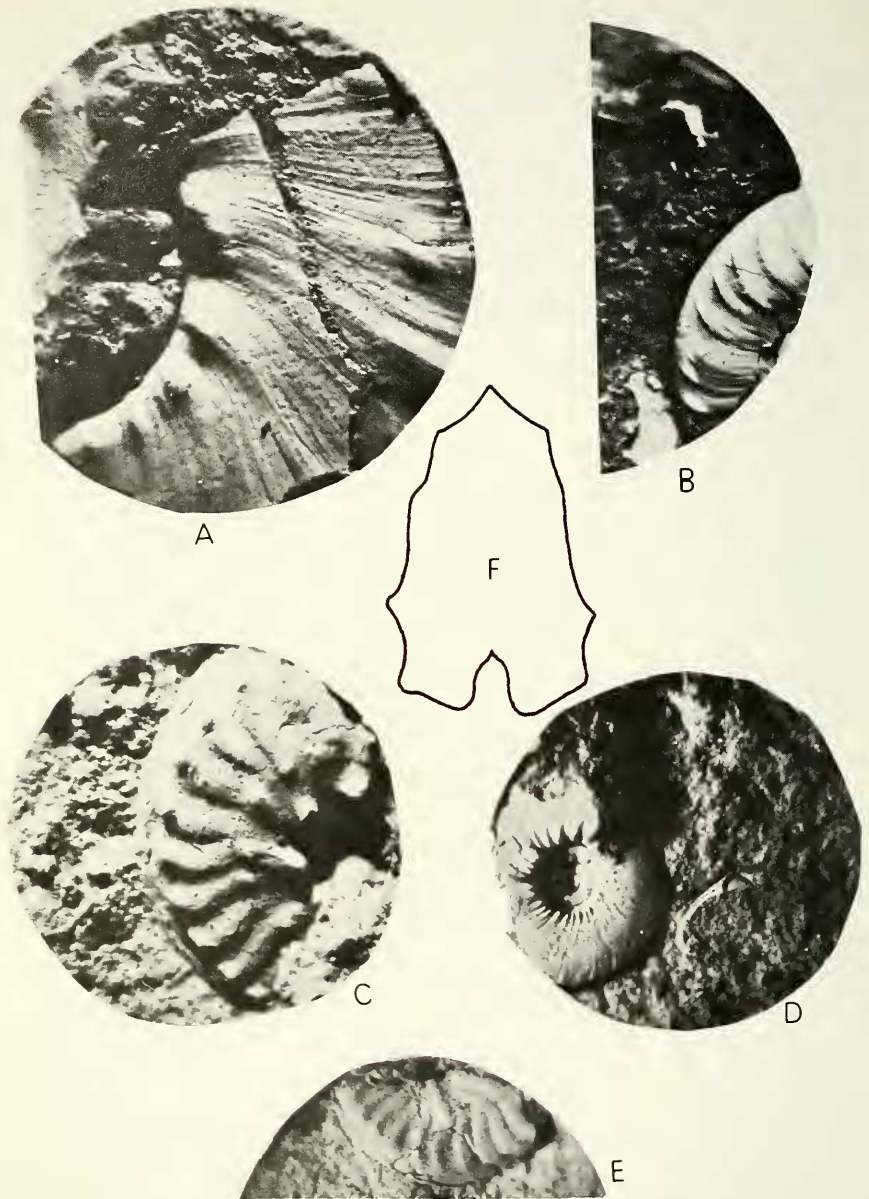
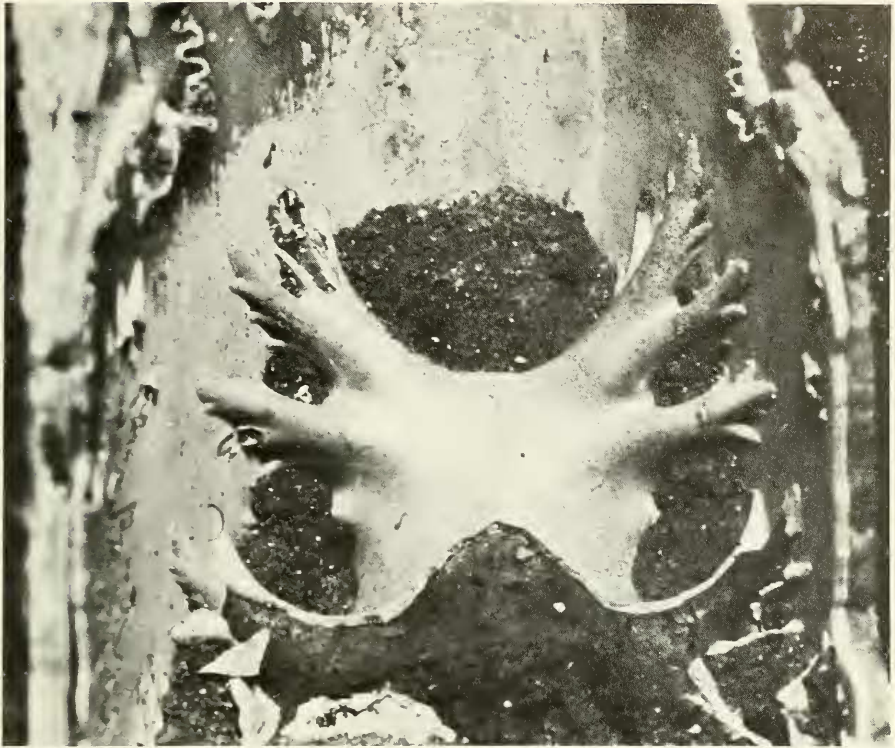


Fig. 6. A. *Pseudoschloenbachia (Vendegiesiella)* sp. cf. *P. (V.) spinosa* Collignon, 1966. BH9/110 ($\times 1,2$). B. *Pseudoschloenbachia (P.) umbulazi* s.l. (Baily, 1855). BH9/135,40 ($\times 1,2$). C. *Pseudoschloenbachia (Vendegiesiella) trituberculata* Collignon, 1966. BH9/108 ($\times 1$). D. *Kosmaticeras (Karapadites)* sp. juv. indet. BH9/102,6. E. *Pseudoschloenbachia (P.) umbulazi* (Baily, 1855) s.l. BH9/123,50 ($\times 1$). F. *Pseudoschloenbachia (Vendegiesiella) trituberculata* Collignon, 1966. BH9/108 ($\times 1,5$).



A

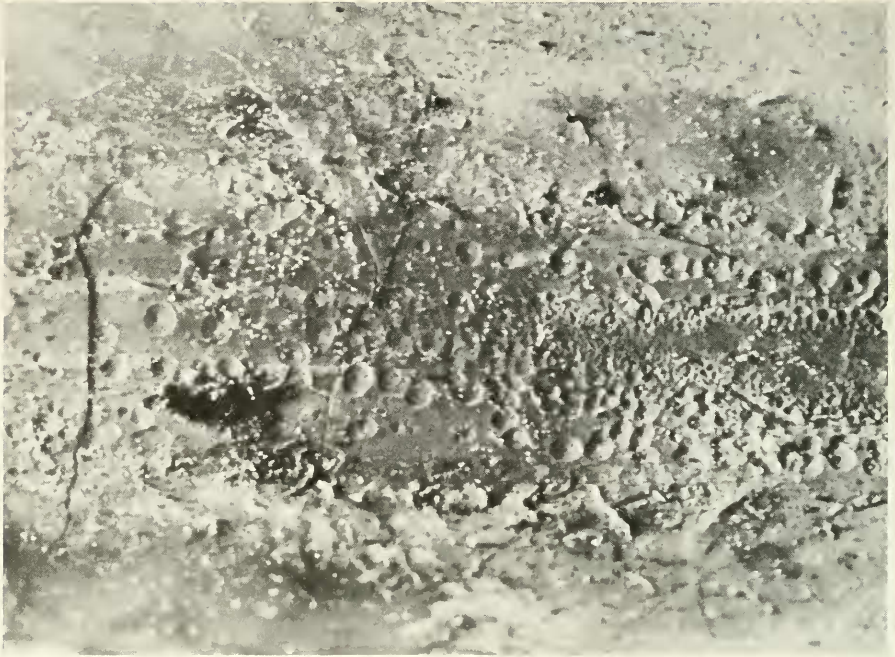


B

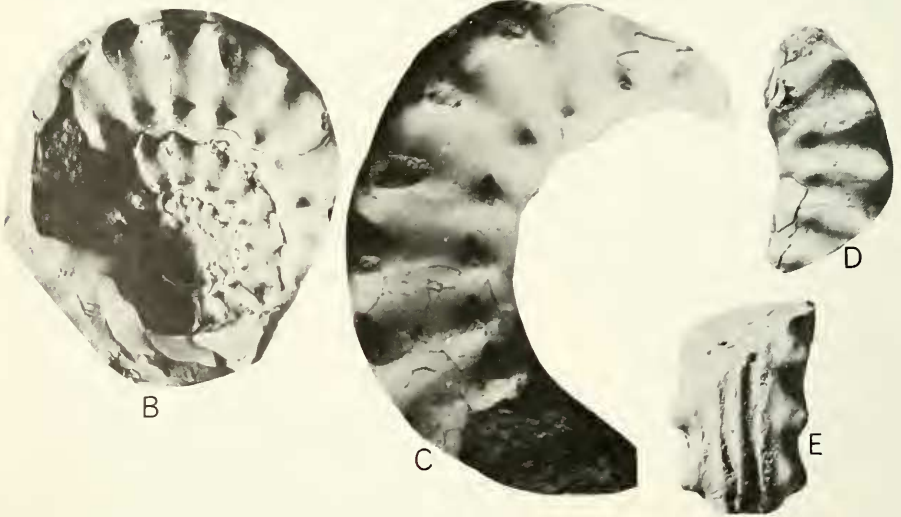


C

Fig. 7. A. *Hauericeras gardeni* (Baily, 1855). BH9/127,80 (\times ca. 8,8). Inner view of specimen to show attachment of septum to inner wall. B. *Hauericeras gardeni* (Baily, 1855). BH9/120,22 (\times 1). C. *Hauericeras gardeni* (Baily, 1855). BH9/127,80 (\times ca. 10).



A



B

C

D

E

Fig. 8. A. *Hauericeras gardeni* (Baily, 1855). BH9/127,80 ($\times ca. 17$). Inner view of siphuncular attachment area to illustrate small conical pits probably representing bases of conellae in the hollow keel. B. *Protexanites* (*Anatexanites*) sp. aff. *P. (A.) nomii* (Yabe & Shimizu, 1925). BH9/121,50 ($\times 1$). Silicone rubber squeeze. C, D, E. *Protexanites* (*Anatexanites*) sp. aff. *P. (A.) nomii* (Yabe & Shimizu, 1925). BH9/121,50 ($\times 1,2$). Outer and inner whorls of remains of specimen.



Fig. 9. *Texanites (T.) soutoni* (Baily, 1855). SAS P1334
($\times 1$). From Umzamba Cliff, Locality 1.



Fig. 10. A. *Protexanites* (*Anatexanites*) sp. aff. *P. (A.) nomii* (Yabe & Shimizu, 1925). SAM-PCP5683 ($\times 1$). B, C. *Texanites* (*T.*) sp. aff. *T. (T.) soutoni* (Baily, 1855). BH9/116 ($\times 1$). D. *Texanites* (*T.*) sp. aff. *T. (T.) soutoni* (Baily, 1855). BH9/118,22 ($\times 1$). Note the faint radial striation in the upper left part of the figure.

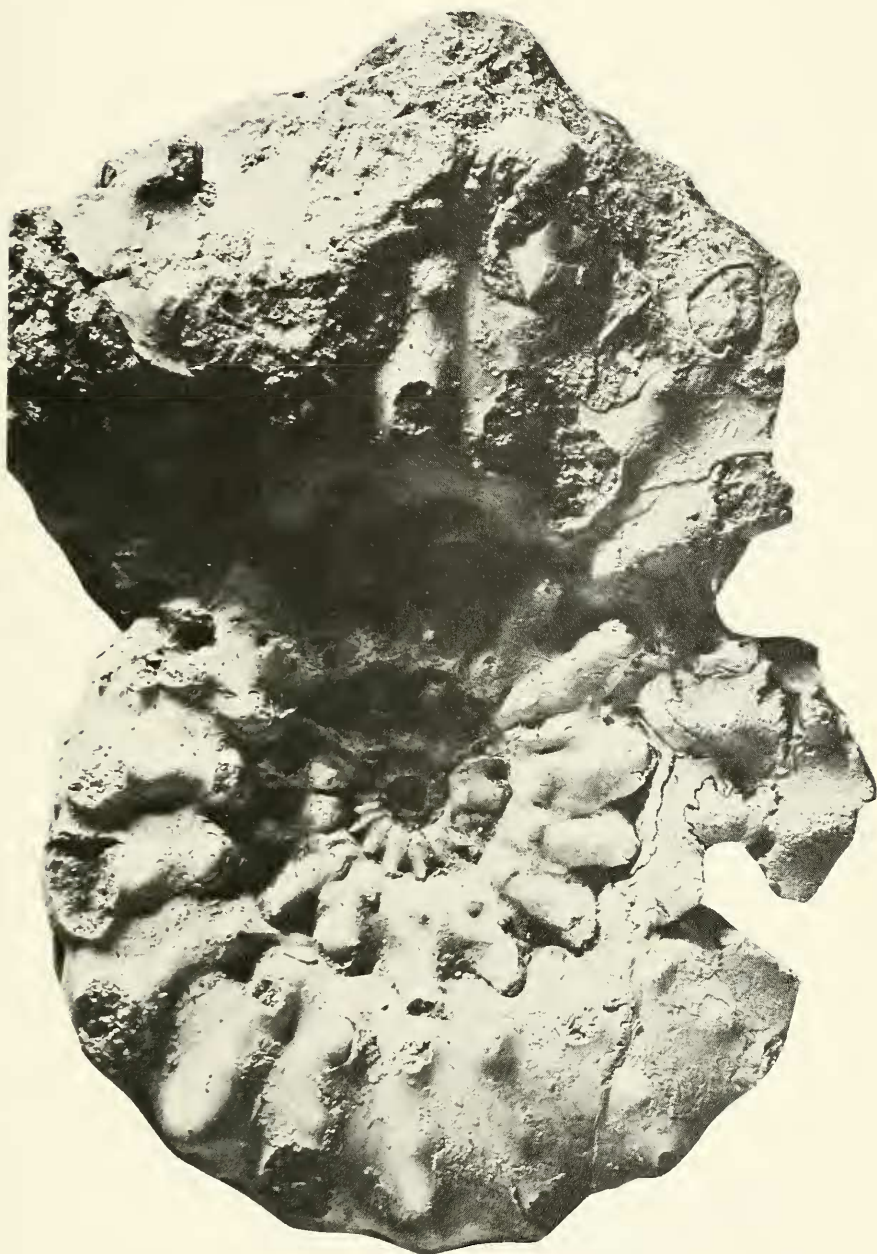


Fig. 11. *Protexanites (Anatexanites) sp. aff. P. (A.) nomii* (Yabe & Shimizu, 1925). SAM-5683 ($\times 1$). Note the appearance of lateral tubercles at bottom of figure.

Exposure at Locality 1, Umzamba Cliff

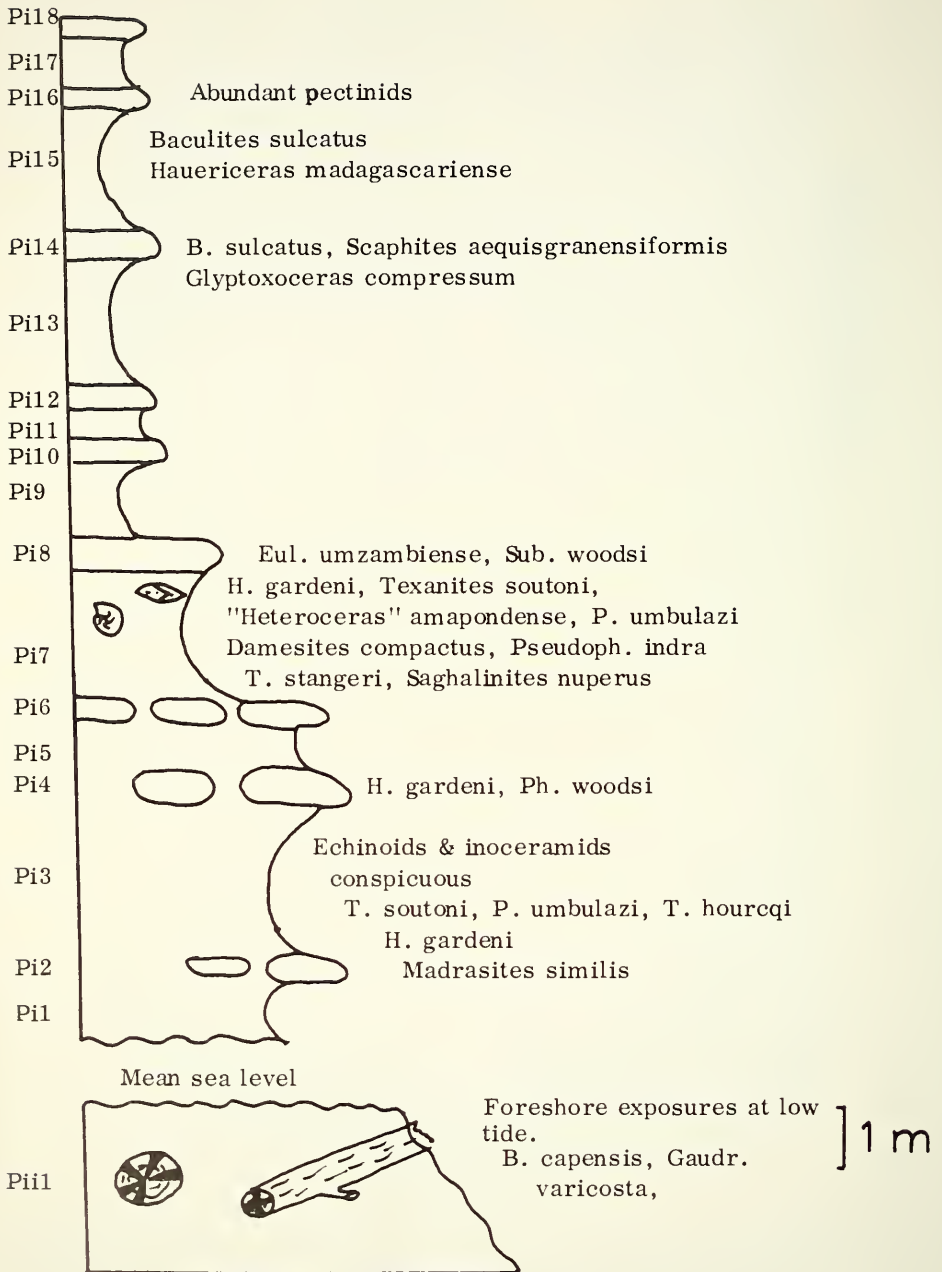


Fig. 12. Exposure at Umzamba Cliff, Locality 1, the type section of the Umzamba Formation (after Klinger & Kennedy, in press).

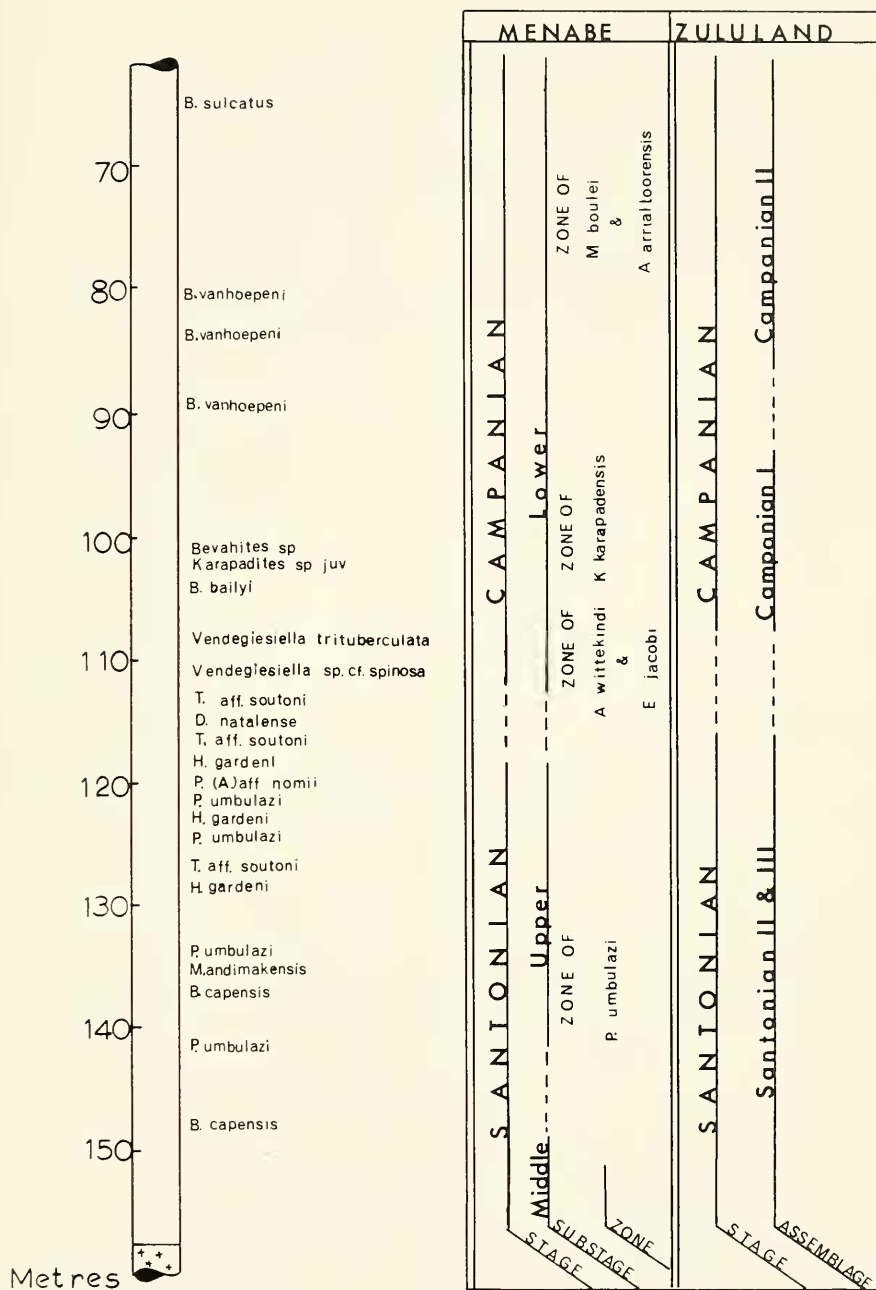


Fig. 13. Schematic diagram of faunal succession in borehole BH9, and comparison with biostratigraphic zonation of Zululand and Menabe.

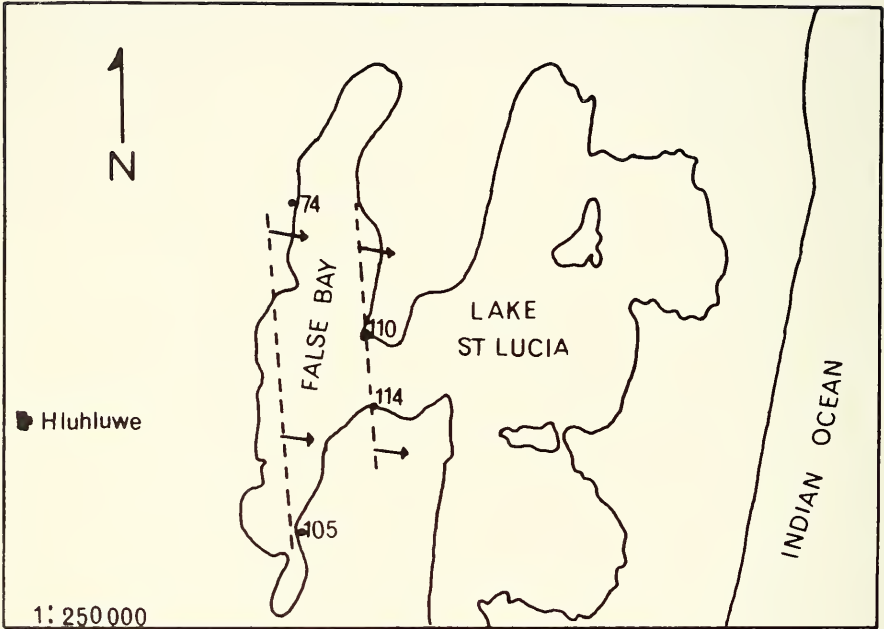


Fig. 14. Sketch map of False Bay-St Lucia area of Zululand indicating location of section used for comparison with BH9 and Umzamba. Section is between two dashed lines.

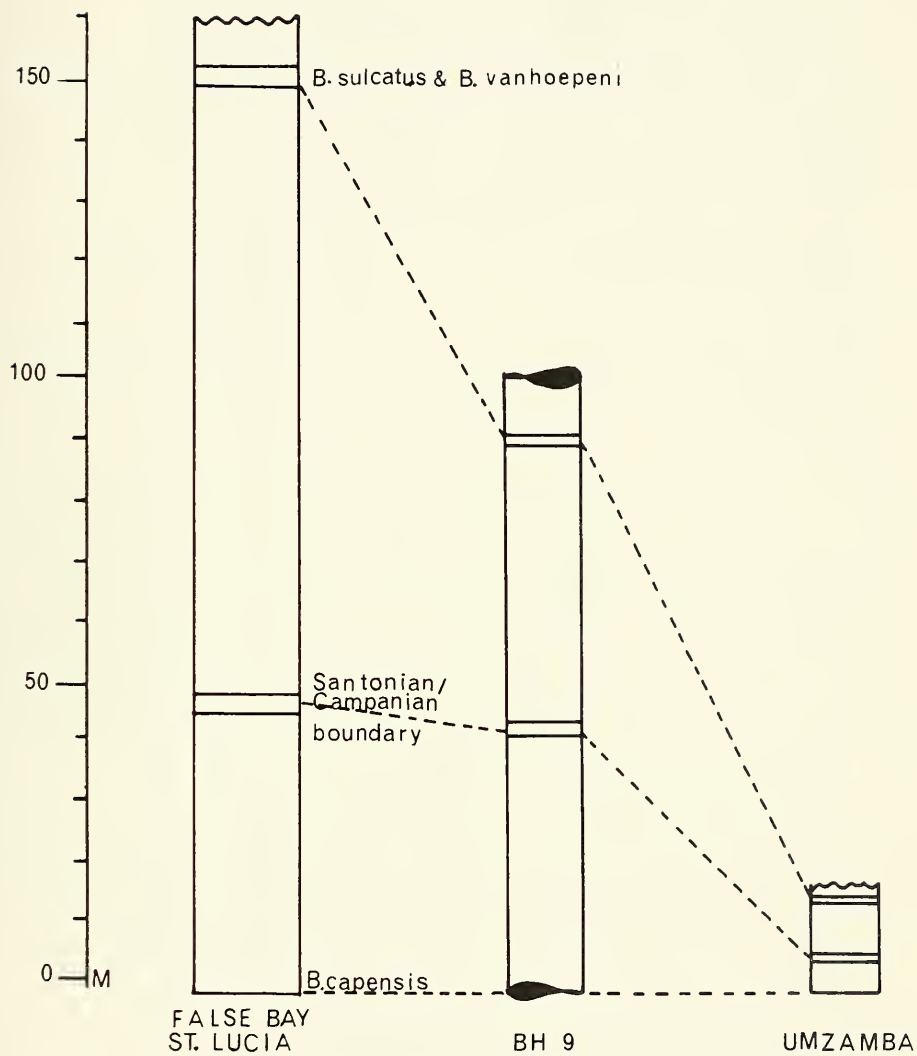


Fig. 15. Correlation of relative thicknesses of sediment at False Bay-St Lucia region, Zululand BH9 at Richards Bay and Locality 1, Umzamba Cliff.

Superfamily ACANTHOCERATACEAE Hyatt, 1900
Family **Collignoniceratidae** Wright & Wright, 1951
Subfamily Texanitinae Collignon, 1948
Genus *Texanites* Spath, 1932

Texanites sp. aff. *T. (Texanites) soutoni* (Baily, 1855)
Figs 5A–B, 9, 10B–D

Compare

Ammonites soutoni Baily, 1855: 455, pl. 11 (fig. 1a–c).

Material

BH9/116, BH9/118,22, BH9/128.

Description

BH9/118,22 (Fig. 10D) is the most complete specimen, consisting of the inner whorls of a texanitid with an estimated diameter of 55 mm. Coiling is moderately involute, with an estimated umbilical width of 30 per cent of the diameter. The innermost whorls are not preserved. At a diameter of 5 mm, two rows of tubercles, situated on prominent ribs, are visible; one at the umbilical edge, the other in the umbilical suture, touching the umbilical wall of the succeeding whorl. At a diameter of 17 mm, lateral tubercles appear at midflank, and rib bifurcations become more frequent. On the outermost whorl the adult ornamentation is visible. The umbilical tubercles are pinched, pointing inwards; the lateral tubercles are small and very slightly clavate. The submarginal and marginal tubercles are situated close to each other on the ventrolateral part of the flanks, and are clavate. The ventral tubercles are the most prominently clavate, and are situated on either side of a prominent rounded keel, which is almost as high as the ventral row of tubercles.

On the outer whorl, there are 19 umbilical tubercles per whorl.

As a result of exceptional preservation, minute details of the surface ornament are visible. The entire test is covered by very fine radial striae, parallel to the ribs. The striation is especially noticeable on the second to fifth rows of tubercles, and over the keel. Ribbing between the second and third rows of tubercles is very flat and almost suggests incipient looping. Part of the suture line is exposed.

BH9/116 (Fig. 10B–C) is part of the phragmocone of a texanitid with the dorsum and part of the flanks preserved and a silicone rubber squeeze of part of the original specimen (Fig. 5B). The impression on the dorsum of the previous whorl leaves no doubt as to the texanitine character of the fragment. The little-inflated flanks, pinched umbilical tubercles and very effaced lateral tubercles strongly suggest affinity with *T. (T.) soutoni*.

BH9/128 (Fig. 5A) is part of the flank of a large whorl. The poorly developed lateral tubercle and close proximity of the marginal and submarginal tubercles again suggest affinities with *T. (T.) soutoni*.

Discussion

For comparative purposes, a typical representative of *T. (T.) soutoni* is included here as Figure 9. It should also be noted that the specimen described by Van Hoepen (1921, pl. 11) as *Mortoniceras soutoni*, with narrow interspaces between the ribs, and briefly commented on by Haas (1942: 17, footnote 3) should be removed from the synonymy of *T. (T.) soutoni*. As can be seen in Van Hoepen's figure, the inner whorls are coarsely costate, in contrast to the fine ribbing in Baily's type. Van Hoepen's specimen also has a different ontogenetic development, as will be discussed in the authors' pending revision of the South African texanitids.

Specimen BH9/118,22 differs from Baily's holotype mainly in being more involute and in having a broader whorl section. In this respect, it bears similarity to Woods's (1906, pl. 63 (fig. 1)) specimen of *Mortoniceras soutoni* which may be a morphological variant or possibly a subspecies of *T. (T.) soutoni*. The specimen described by Spath (1921: 235) as *Mortoniceras* sp. aff. *soutoni* (SAM-K5492) from Umkwelane Hill near Mtubatuba has a very faint lateral tubercle on the inner whorl, as in the typical *T. (T.) soutoni*, but develops stronger tuberculation on the outer whorl.

Texanites (T.) hourcqi Collignon (1948: 78 (33), pl. 7(1)(figs 1, 1a–b), pl. 10(4) (figs 1, 1a)); 1966: 70, pl. 484 (fig. 1957)) is a related species, but has a different height to breadth ratio, and denser ribbing.

T. (Plesiotechanites) stangeri and its varieties (Baily, 1855: 455, pl. 11 (fig. 2); Kennedy & Klinger, 1973: 102, 103, pl. 5 (fig. 2a–b), pl. 6 (fig. 3a–b)) have much stronger tuberculation at similar diameters, a broader whorl section, and the lateral tubercle only appears at a very late stage.

Occurrence

Texanites (T.) soutoni is best known from the Umzamba Formation, and no typical representative has as yet been found in the False Bay–St Lucia region of Zululand. At the type locality of the Umzamba Formation (Fig. 12) *T. (T.) soutoni* occurs in beds Pi1 to Pi7, appearing to be most abundant in Pi3. In Madagascar *T. (T.) soutoni* occurs in the Middle Santonian Zone of *Texanites (T.) hourcqi*. The species appears to be restricted to the Santonian of southern Africa and Madagascar.

Genus *Bevahites* Collignon, 1948

Bevahites (?) sp. indet.

Fig. 5H–I

Material

BH9/101,7.

Description and discussion

Only a small fragment of what appears to be a representative of *Bevahites* is available. The specimen bears small, pointed lateral tubercles, connected to

slightly larger clavate submarginal tubercles by broad, low rounded ribs. The marginal tubercles are situated a small distance away from the latter, and are distinctly clavate. Intercalated ribs are present and, in consequence, there are more marginal and external tubercles than submarginal. The ventral tubercles are small and clavate, situated on either side of a prominent keel.

Specific identification based on this small specimen is impossible.

Occurrence

At Menabe, Madagascar, *Bevahites* is restricted to the uppermost part of the Late Santonian Zone of *Pseudoschloenbachia umbulazi* and the Early Campanian Zone of *Anapachydiscus wittekindi* and *Eulophoceras jacobi*.

Genus *Protexanites* Matsumoto, 1955

Subgenus *Anatexanites* Matsumoto, 1970

Protexanites (*Anatexanites*) sp. aff. *P. (A.) nomii* (Yabe & Shimizu, 1925)

Figs 8B-E, 10A, 11

Compare

Mortonicerias nomii Yabe & Shimizu, 1925: 131, pl. 32 (figs 1-3).

Protexanites (*Anatexanites*) *nomii* (Yabe & Shimizu); Matsumoto, 1970: 242, pl. 32 (figs 1-2), text-fig. 7.

Material

BH9/121,50 from Richards Bay and SAM-PCP5683 from the Umzamba Estuary, Pondoland.

Description

The actual borehole material consists of parts of two successive whorls. Fortunately, however, the original external mould of the inner whorls was preserved, and a silicone rubber squeeze taken. A specimen from Umzamba (South African Museum collections) with virtually identical inner whorls is included for comparison.

Coiling is evolute, with an umbilical diameter of about 44 to 46 per cent of the total diameter. For *Protexanites* the species reaches a large size; the Umzamba specimen is still septate at a diameter of 145 mm. On the inner whorls, whorl breadth exceeds whorl height, but the whorl height increases gradually until it eventually exceeds whorl breadth.

Ornament on the inner whorl consists of rather weak, single, radial to slightly prorsiradiate ribs, each bearing a small, pointed, umbilical tubercle, and a large, spinose, ventrolateral tubercle, which is in contact with the umbilical wall of, and in some cases virtually reaches up to the umbilical tubercle of, the succeeding whorl. From the inner whorl of BH9/121,50 it appears as if the ventral tubercles formed a virtual discontinuous keel on either side of the median keel. On the outer whorls, however, the ventral tubercles are separated, although

highly elongate and clavate. On the Umzamba specimen, lateral tubercles appear at a diameter of 70 mm, and, on the last part of the phragmocone preserved, are as large as the umbilical tubercles.

With the appearance of the lateral tubercles the ventrolateral tubercles become less spinose and more bullate, but are still very strong. On the inner whorls rib density is 15 per whorl, on the outer, 20.

Only part of a badly corroded suture line is preserved.

Dimensions

<i>Specimen</i>	<i>D</i>	<i>Wb</i>	<i>Wh</i>	<i>Wb/Wh</i>	<i>U</i>
BH9/121,50	49	—	—	—	23 (46)
BH9/121,50	—	13	11	1,18	—
SAM-PCP5683	81	28 (34,5)	31 (38,2)	0,90	36 (44)

Discussion

The present material closely resembles the Japanese species recently discussed extensively by Matsumoto (1970: 242–5). In particular the inner whorls are very similar (see Matsumoto 1970, pl. 32 (figs 7a–c)). Rib density is similar (15 per whorl on the inner whorls), and the ribs are all single and straight. The only apparent difference is that the ventrolateral tubercles are not as strongly developed in the Japanese material. On the basis of the available specimen it is not known whether these differences are of specific significance or not, for the outer whorls of the Umzamba specimen are not preserved.

For further comparison with other species of *Protexanites*, see Matsumoto (1970: 244–5).

The inner whorls of the Richards Bay specimens closely resemble *Texanites* (*Plesiotexanites*) *stangeri*, especially the sparsely ribbed variety, but differs in having single ribs throughout.

Occurrence

The Japanese specimens are of Santonian age. The Umzamba specimen is of Middle Santonian age, occurring on the south side of the estuary at a horizon approximately equivalent to bed Pi2 at the type section.

Family **Muniericeratidae** Wright, 1952

Subfamily Pseudoschloenbachinae Collignon, 1969

Genus *Pseudoschloenbachia* Spath, 1921

Subgenus *Pseudoschloenbachia* Spath, 1921

Pseudoschloenbachia (*P.*) *umbulazi sensu lato* (Baily, 1855)

Fig. 6B, E

Ammonites umbulazi Baily, 1855: 456, pl. 11 (fig. 4).

Schloenbachia umbulazi (Baily); Woods, 1906: 336. Van Hoepen, 1921: 35.

Pseudoschloenbachia umbulazi (Baily); Spath, 1921: 240, pl. 20 (figs 2–3), text-figs B7–7; 1922: 139, pl. 6 (fig. 5).

Pseudoschloenbachia (*Pseudoschloenbachia*) *umbulazi* (Baily); Collignon, 1966: 103, pl. 659 (figs 1996–1999).

Holotype

The specimen figured by Baily (1855, pl. 11 (fig. 4)).

Material

BH9/123,50, BH9/135,40.

Description and discussion

Neither of the two specimens is sufficiently well preserved for allocation to one of the numerous subspecies or varieties centred around *P. umbulazi*. For the present, however, narrowly umbilicate compressed section and the presence of falcoid ribbing are regarded as being sufficient for allocation to *P. (P.) umbulazi*.

Occurrence

P. (P.) umbulazi is the zonal index of the Late Santonian of Menabe, Madagascar. The species and its variants occur in profusion in Pondoland in horizon Pi7 at Umzamba (Fig. 12), and are common in Pi3. From the data available, it appears that *P. (P.) umbulazi* s.s. is gradually replaced by the varieties (or subspecies) *griesbachi* and *spinifera* towards the top at the Santonian–Campanian boundary. *P. (P.) umbulazi* s.l. is relatively rare in the False Bay–St Lucia area of Zululand.

Subgenus *Vendegiesiella* Collignon, 1969

Pseudoschloenbachia (*Vendegiesiella*) sp. cf. *P. (V.) spinosa* Collignon, 1969

Fig. 6A

Compare

Pseudoschloenbachia (*Vendegiesiella*) *spinosa* Collignon, 1969: 101, pl. 553 (figs 2156–2157).

Material

BH9/110.

Description and discussion

One side of a flat-sided pseudoschloenbachiid with dense, fine, falcoid striation, and hardly any sign of ribbing and with umbilical and lateral tubercles is referred to *Vendegiesiella*. The venter is not preserved.

At first glance the specimen resembles fragments of large specimens of *Pseudoschloenbachia* (*P.*) *umbulazi griesbachi* (see Van Hoepen 1921: 35, pl. 7 (figs 3–4), pl. 8 (figs 1–5)). The wide umbilicus and the presence of lateral tubercles, however, point to *Vendegiesiella*. Affinities are to be found in the type species, *P. (V.) spinosa* Collignon (1969: 101, pl. 553 (figs 2156–2157)) and *P. (V.)*

densecapillata Collignon (1969: 103, pl. 554 (fig. 2159), pl. 555 (fig. 2161)). According to M. Collignon (letter 17.4.1976) it is considered advisable to refer to the specimen as *P. (V.)* sp. cf. *P. (V.) spinosa*.

Occurrence

The Madagascan species occurs in the Lower Campanian Zone of *Anapachydiscus wittekindi* and *Eulophoceras jacobi*, Subzone of *Besairiella besairiei*.

Pseudoschloenbachia (Vendegiesiella) trituberculata Collignon, 1969

Fig. 6C, F

Pseudoschloenbachia (Vendegiesiella) trituberculata Collignon, 1969: 107 pl. 556 (figs 2156–2165).

Description

The specimen consists of less than a quarter of a phragmocone whorl and a silicone rubber squeeze of less than half a whorl of the original specimen. The whorl section is keeled (Fig. 6F) and shouldered. The umbilical wall is virtually vertical. The flanks in intercostal section are flat and converge to a narrow, ventrolateral shoulder. The venter is ornamented by a thin, finely crenulate keel. The umbilical tubercles are strongest, numbering about five per half whorl, and are pointed to conical, pointing inward. From the tubercles a rib arises which soon bi- or trifurcates in falcoid fashion on the dorsal third of the flanks. Intercalary ribs appear to arise at the same point. At the point of bi- or trifurcation, conical lateral tubercles occur. On the venter the ribs terminate in spirally elongated tubercles, numbering about fourteen per half whorl.

Discussion

This specimen is virtually identical to Collignon's (1969, pl. 556 (fig. 2163)) specimen and no doubt exists as to its identity.

Occurrence

In Madagascar the species occurs in the Lower Campanian Zone of *Anapachydiscus wittekindi* and *Eulophoceras jacobi*, Subzone of *Hourcquiella bererensis*. According to M. Collignon the previously described species *P. (V.) spinosa* occurs at a slightly lower level than *P. (V.) trituberculata*. Together these species thus seem to indicate a horizon in the middle of the Zone of *Anapachydiscus wittekindi* and *Eulophoceras jacobi*.

STRATIGRAPHY AND CORRELATION

The faunal succession in the borehole is shown in Figure 13. For determination of the age of the faunas, and to determine biostratigraphic boundaries, the faunal divisions recognized in Natal and Zululand by Kennedy & Klinger (1975:

273–281) and Menabe (Madagascar) by Collignon (1969: 5) have been used. In spite of Collignon's (1969: 4) emphasis of the local nature of his zonation, and indeed, his view that it was only applicable to Menabe (Madagascar), it was found previously (Klinger & Kennedy, in press) that it was also applicable to some parts of the South African Cretaceous System, specifically the Umzamba Formation at the type section.

CORRELATION WITH ZULULAND AND NATAL

The following species are critical for demarcating stage boundaries and recognizing faunal divisions.

1. *Texanites* (*T.*) *soutoni*, abundant *Pseudoschloenbachia umbulazi* and *Hauericeras gardeni* are indicative of the second and third divisions of the Santonian (Santonian II & III).

2. *Baculites vanhoepeni* indicates the second division of the Campanian (Campanian II).

CORRELATION WITH MENABE, MADAGASCAR

The following species are critical for defining stage and zonal boundaries:

1. *Baculites capensis* marks either the Early or Middle Santonian, most probably Middle Santonian.

2. *Pseudoschloenbachia umbulazi* s.l. is indicative of the Late Santonian Zone of *Pseudoschloenbachia umbulazi*.

3. *Pseudoschloenbachia* (*Vendegiesiella*) spp. are indicative of the Early Campanian Zone of *Anapachydiscus wittekindi* & *Eulophoceras jacobi*.

4. *Bevahites* species mark the base of the succeeding Early Campanian Zone of *Karapadites karapadensis*.

5. *Baculites vanhoepeni* and *Baculites sulcatus* appear to mark the upper part of the Zone of *Karapadites karapadensis*, or the lower part of the succeeding Zone of *Menabites boulei* and *Anapachydiscus arrialoorensis*. At Umzamba Cliff, *B. sulcatus* occurs together with *Hauericeras madagascariense*, which, according to Collignon (1969: 66), is restricted to the Zone of *Menabites boulei* & *Anapachydiscus arrialoorensis*, subzone of *Rabeiella orthogonia*.

DISCUSSION OF RESULTS AND REGIONAL IMPLICATIONS

Geological history

By using both the biozonations compiled for Zululand and Natal (Kennedy & Klinger 1975) and that for Menabe, Madagascar (Collignon 1969) an age of Middle or early Late Santonian is estimated for the faunas occurring at a depth of 148 metres, only 10 metres above the unconformable contact with the Basement rocks in the Richards Bay borehole, and a late Early Campanian (Campanian II) age is indicated for faunas occurring at a depth of 64 metres approximately 100 metres from the base. This is at variance with Maud & Orr's (1975: 103) age determinations, for on the basis of microfaunal assemblages, a late Campanian to early Maastrichtian age was allocated to the sediments at a depth

of 158 metres, and 'apparently Maastrichtian' microfaunas were recorded at a depth of 57 metres. Maud & Orr (1975: 103) furthermore state that the fauna at a depth of 158 metres, consisting of *Baculites* and *Inoceramus*, is comparable with that of Charter's Creek, Zululand. This is the same locality as Kennedy & Klinger's (1975: 298) locality 133, and the exposures there are indeed of Maastrichtian age (Maastrichtian I), containing a characteristic Lower Maastrichtian fauna including abundant *Eubaculites latecarinatus* (Brunnschweiler) and *Saghalinites cala* (Forbes). None of these diagnostic faunal elements occurs in the BH9 core and, from the ammonite faunas present, a Late Campanian or Early Maastrichtian age for the base of the borehole sequence is not acceptable.

The age of these borehole fauna is of some importance in clarifying the Cretaceous history of south-eastern Africa. In the northern part of Zululand, a virtually complete sequence of sediments ranging from Late Barremian to Late Cenomanian age with a small hiatus between the Upper Aptian and Lower Albian was deposited. During the Late Cenomanian, the whole of the Turonian and part of the Early Coniacian, erosion and/or non-deposition are reflected in a major intra-Late Cretaceous unconformity (Kennedy & Klinger 1971). Transgression followed this period of erosion and/or non-deposition, and the base of the transgressive sequence is diachronous. Along the Mzinene River in the north, the base of the sequence is of Early Coniacian date (Coniacian I). To the south, in the environs of Mtubatuba (Umkwelane Hill), the Cretaceous overlaps on to Stormberg Basalts and granitic Basement rocks and the base is of slightly later date, although still Early Coniacian (Coniacian II).

In the extreme south, at Umzamba Cliff (Kennedy & Klinger 1975, Locality 1), the Cretaceous rests directly on Ordovician(?) Table Mountain Group sandstones and quartzites. The basal Cretaceous sediments here are of Middle Santonian age (Klinger & Kennedy, in press). The Late Coniacian age attributed to the base of the Umzamba Formation by Kennedy & Klinger (1975: 281) is a result of misidentification of the type material of '*Muniericeras*' *cricki* Spath (= '*Barroisiceras*' *unzambiense* Van Hoepen). The species is in fact a *Lehmaniceras*, a Middle Santonian genus known from Madagascar (Collignon 1966) which is a homoeomorph of the Coniacian *Subprionotropis* to which the authors previously attributed it.

The dating of faunas only 10 metres from the base of the Richards Bay sequence thus fall between the dates of the base of the Umkwelane Hill sequence to the north and the Umzamba Cliff sequence to the south, confirming the southerly-younging of the base of the transgressive deposits.

The date of the base of the Upper Cretaceous succession below Durban is unknown, but fauna recently described (Kennedy *et al.* 1973) indicate that beds of Late Santonian to Early Campanian age are present.

All these data seem to suggest that the initial post-Turonian transgression was gradual and of only limited extent, probably reaching only a short distance south of Umkwelane Hill. This was followed by a rapid transgressive pulse during Middle or Late Santonian time, leading to the deposition of the Cretaceous

sediments in the Richards Bay, Durban and Umzamba regions, with the commencement of deposition essentially synchronous along the whole of this latter stretch of south eastern Africa.

Regional affinities of the Richards Bay fauna

The faunal divisions recognized in Zululand by Kennedy & Klinger (1975) can be applied to the Richards Bay sequence, but a higher degree of biostratigraphic resolution is possible by application of Collignon's bio-zonation based on Menabe, Madagascar, despite the latter's (Collignon 1969: 4) emphasis that the zonation was purely local.

With the exception of the baculitids of the group *B. vanhoepeni* and *B. sulcatus*, and *Hauericeras gardeni*, the Richards Bay borehole fauna shows greater similarity to those of Umzamba (Pondoland) and Durban, and, to a lesser extent Mtubatuba (Umkwelane Hill and environs) than to the fauna known from False Bay–St Lucia areas of Zululand. *P. (P.) umbulazi* and its variants occur in profusion at Umzamba and at Richards Bay (Kennedy & Klinger 1975, Locality 6), but are relatively scarce in the False Bay–St Lucia area, constituting only a minor part of most faunas. The abundance of *T. (T.) soutoni* and *T. (P.) stangeri* at the Umzamba exposure and in the Richards Bay subsurface (BH9 and at Locality 6), but the virtual absence of these species in the False Bay–St Lucia area, is also striking, whilst it is equally interesting to note the presence of the subgenus *Pseudoschloenbachia (Vendegiesiella)* at Richards Bay, which was previously known only from Madagascar.

It seems unlikely, however, that all these regions, in open marine connection with each other, are faunally distinct because of real differences in fauna. More probably, this horizon is one which is poorly exposed in Zululand. Certainly there are many levels in the area where quite distinctive faunas, characterized by great abundance of only a few genera, are limited to only a few metres of section.

On the other hand, faunal differences between Pondoland and Zululand may reflect ecological controls such as depth of water and proximity of the shoreline.

COMPARISON OF SEDIMENT THICKNESSES

Sufficient data are available to compare the thicknesses of sections of the False Bay–St Lucia area, Richards Bay BH9 and Umzamba, Pondoland (although about 100 metres of Cretaceous sediments are present subsurface below Durban, no precise stratigraphic control is available, and these sections are not considered here).

Data for the Umzamba exposure (Fig. 12) are taken from Klinger & Kennedy (1976, in press). The base level for correlation is taken at the appearance of *B. capensis*, and the upper limit at the level of the last occurrence of *B. vanhoepeni* and *B. sulcatus*, whilst the authors have also located the Santonian–Campanian boundary in all sections. In the False Bay–St Lucia area an eastward

dip of 3 degrees is assumed, giving a thickness of about 160 metres for this interval. As shown in Figure 15, there is a marked attenuation of the sequence in the short distance from the False Bay–St Lucia region to Richards Bay, and this continues southwards. The attenuation is not simply a reflection of the diachronism, but is due to sedimentary thinning, presumably as a consequence of differential subsidence.

SUMMARY

In a vertical borehole section of 100 metres at Richards Bay, Middle Santonian to Early Campanian faunas are recognized on the basis of comparison with the faunal successions in Zululand (South Africa) and Menabe (Madagascar) respectively. In the Upper Santonian and parts of the Lower Campanian, the faunal sequence matches closely the Malagasy succession compiled by Collignon (1969) and the Zululand and Natal successions compiled by Kennedy & Klinger (1975).

The Late Cretaceous transgression which flooded areas to the north in the False Bay–St Lucia area during Coniacian time, reached Richards Bay, Durban and Pondoland simultaneously in Middle Santonian time. The thickness of sediment representing the Middle Santonian to Lower Campanian interval is reduced from 160 metres in the False Bay–St Lucia area to 100 metres at Richards Bay and Durban, and only 17 metres at Umzamba. This thinning is not simply the result of diachronism; it reflects true sedimentary thinning, presumably as a result of differential subsidence.

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